US009235903B2

(12) **United States Patent**
Song et al.

(10) **Patent No.: US 9,235,903 B2**
(45) **Date of Patent: Jan. 12, 2016**

(54) **IMAGE PROCESSING SYSTEM WITH AUTOMATIC SEGMENTATION AND METHOD OF OPERATION THEREOF**

(71) Applicant: **Sony Corporation**, Tokyo (JP)

(72) Inventors: **Bi Song**, San Jose, CA (US); **Ming-Chang Liu**, San Jose, CA (US)

(73) Assignee: **Sony Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 12 days.

(21) Appl. No.: **14/244,470**

(22) Filed: **Apr. 3, 2014**

(65) **Prior Publication Data**

US 2015/0287210 A1 Oct. 8, 2015

(51) **Int. Cl.**

G06K 9/34 (2006.01)
G06K 9/36 (2006.01)
G06T 7/00 (2006.01)
G06T 11/60 (2006.01)

(52) **U.S. Cl.**

CPC ***G06T 7/0081*** (2013.01); ***G06K 9/34*** (2013.01); ***G06T 7/0083*** (2013.01); ***G06T 11/60*** (2013.01); *G06T 2207/20141* (2013.01); *G06T 2207/20148* (2013.01); *G06T 2207/20152* (2013.01)

(58) **Field of Classification Search**

USPC 382/173, 284
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,075,875 A * 6/2000 Gu G06T 7/0081
375/E7.04
6,975,875 B2 * 12/2005 Lee et al. 455/458
7,366,348 B2 4/2008 Watson
7,873,214 B2 * 1/2011 Shaw et al. 382/173
8,260,048 B2 9/2012 Jin
2004/0258305 A1 * 12/2004 Burnham et al. 382/171
2005/0129312 A1 * 6/2005 Ernst et al. 382/173
2009/0238457 A1 9/2009 Rittscher et al.
2010/0066761 A1 3/2010 Tousch et al.
2011/0075927 A1 * 3/2011 Xu G06K 9/6224
382/173
2013/0094750 A1 4/2013 Tasdizen et al.

FOREIGN PATENT DOCUMENTS

EP 0483299 B1 5/1992

OTHER PUBLICATIONS

Haris et al., "Hybrid Image Segmentation Using Watersheds and Fast Region Merging", "IEEE Transactions on Image Processing", Dec. 1998, pp. 1684-1699, vol. 7, No. 12, IEEE.
Salman, "Image Segmentation Based on Watershed and Edge Detection Techniques", "The International Arab Journal of Information Technology", Apr. 2006, pp. 104-110, vol. 3, No. 2.

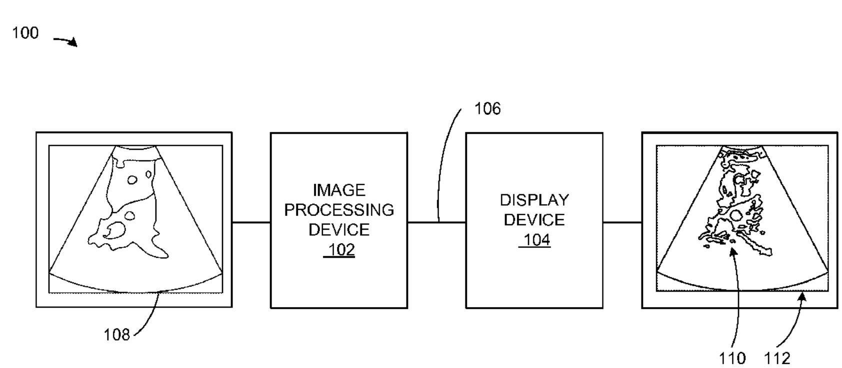
* cited by examiner

Primary Examiner — Kanjibhai Patel
(74) *Attorney, Agent, or Firm* — Ishimaru & Associates LLP

(57) **ABSTRACT**

An image processing system and method of operation includes: a source image having source pixels; a homogeneity image module for forming a homogeneity image having homogeneity pixels each with a homogeneity value indicating the local homogeneity of source pixels of the source image; a watershed image module, coupled to the homogeneity image module, for forming a watershed image having watershed segments with a segment weight, the watershed image formed by segmenting the homogeneity image, and for merging one of the watershed segments with another of the watershed segments both having the segment weight less than or equal to a segment threshold; a contour map module, coupled to the watershed image module, for forming a segmentation contour map having boundaries of the watershed segments formed by merging the watershed segments; and a composite image module for forming a composite image with the segmentation contour map for display on a device.

10 Claims, 8 Drawing Sheets



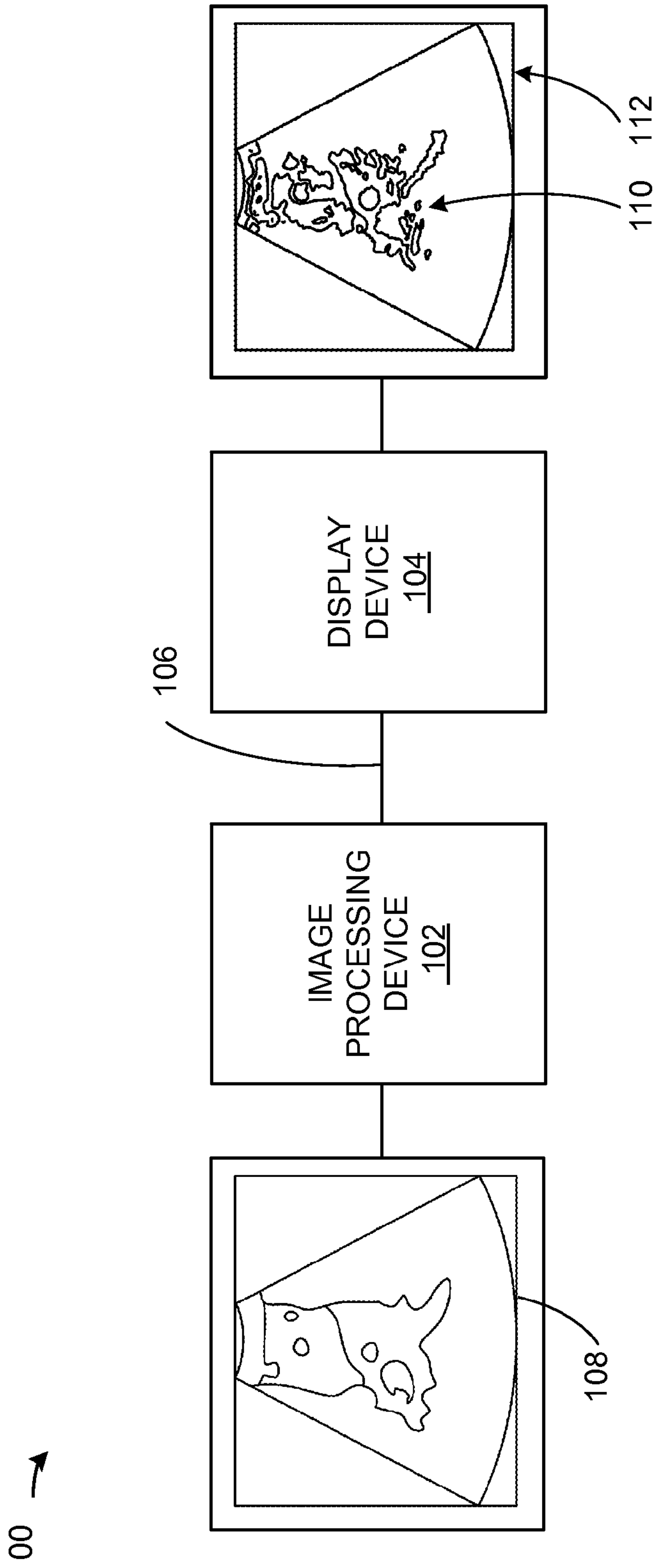

100
108
IMAGE PROCESSING DEVICE 102
106
DISPLAY DEVICE 104
110
112

FIG. 1

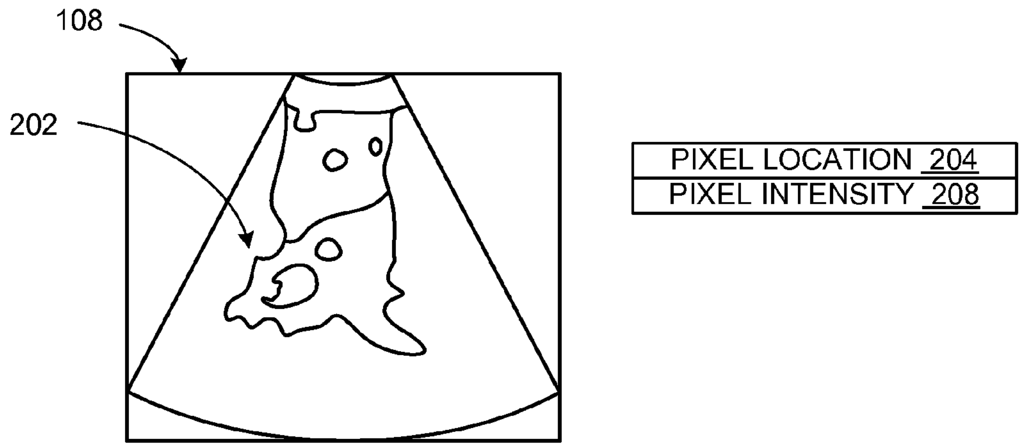


FIG. 2

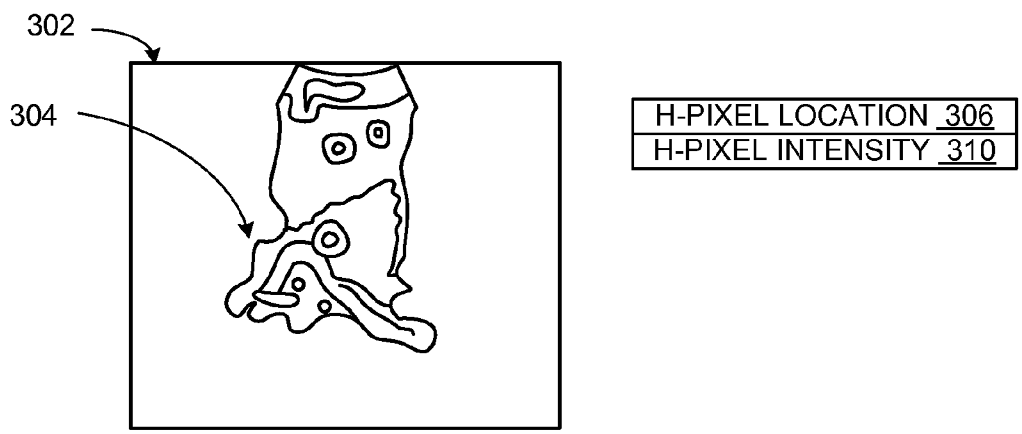


FIG. 3

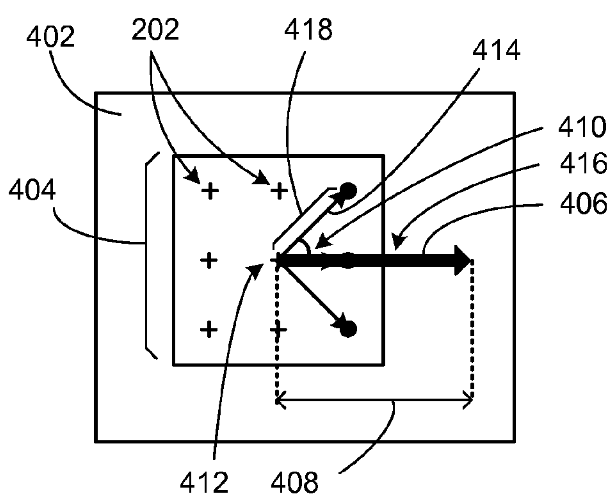
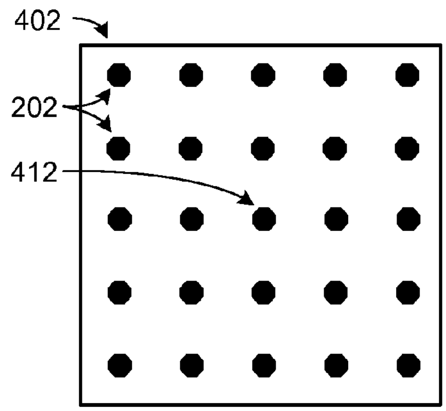
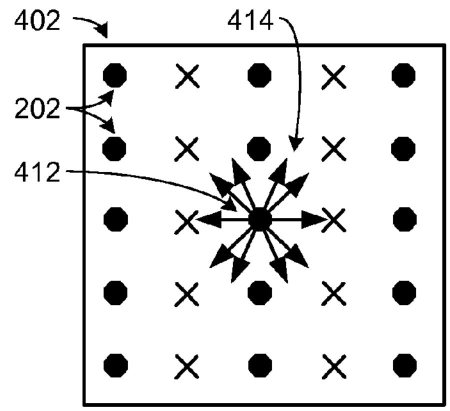


FIG. 4



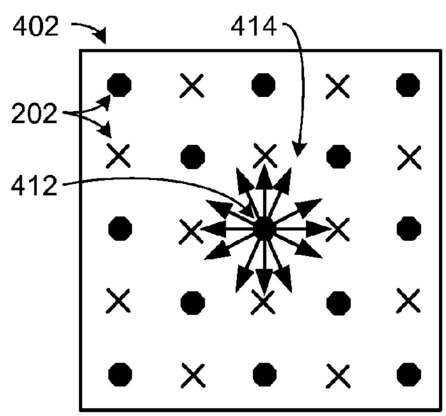
(A) $H = 0$

FIG. 5



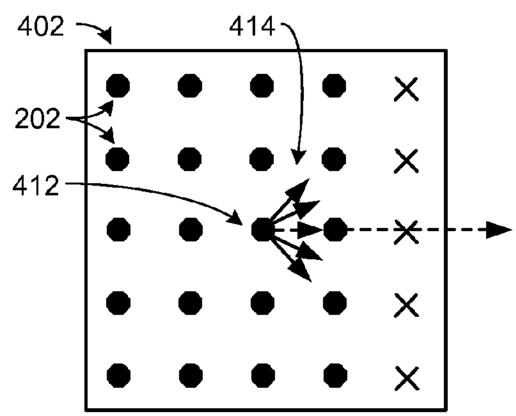
(B) $H = 0$

FIG. 6



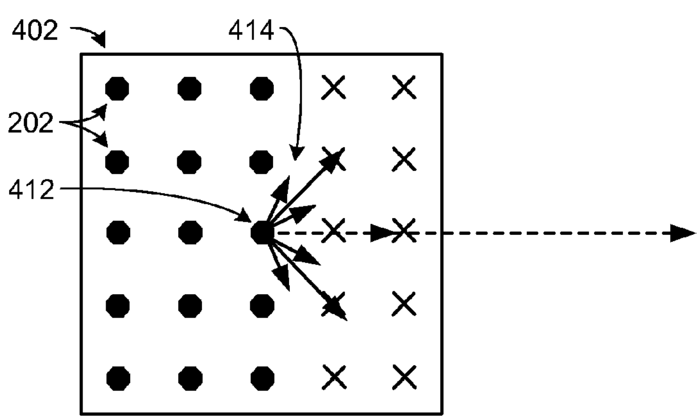
(C) $H = 0$

FIG. 7



(D) $H \approx 4.2 \cdot D$

FIG. 8



(E) $H \approx 7.5 \cdot D$

FIG. 9

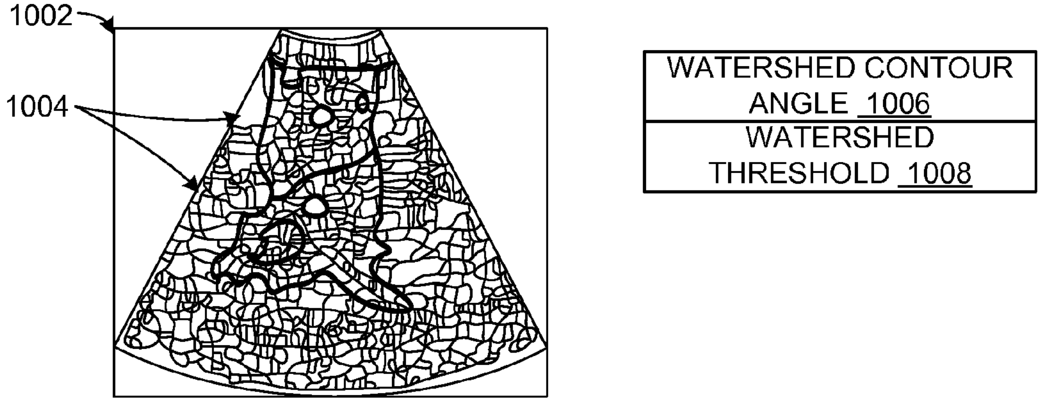


FIG. 10

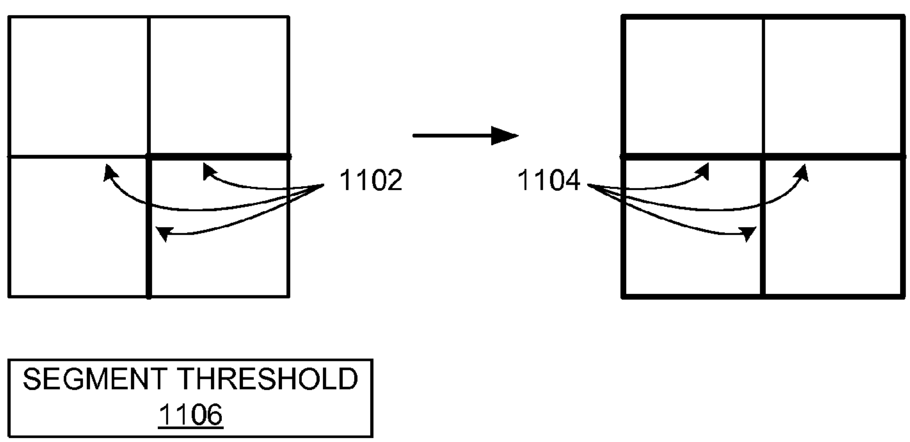


FIG. 11

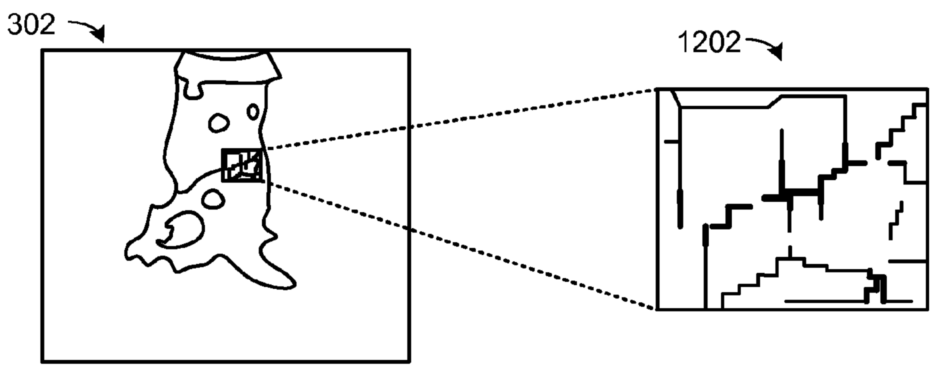


FIG. 12

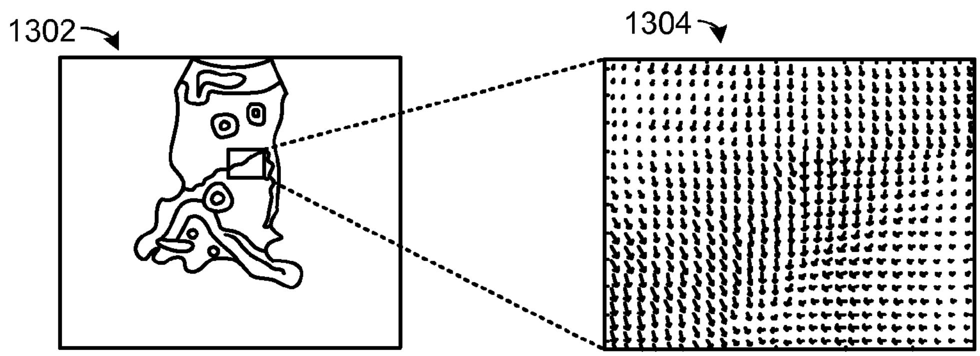


FIG. 13

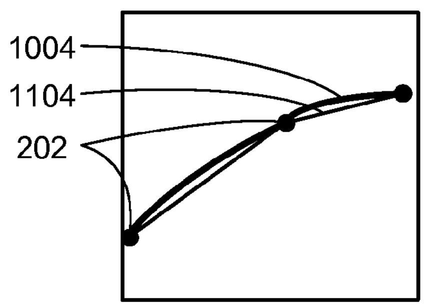


FIG. 14

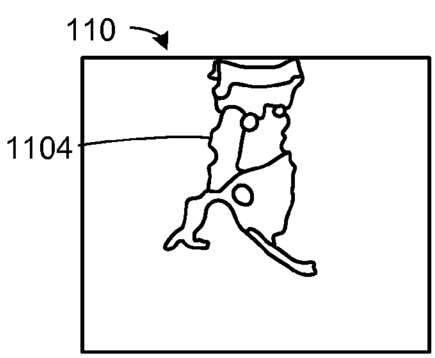


FIG. 15

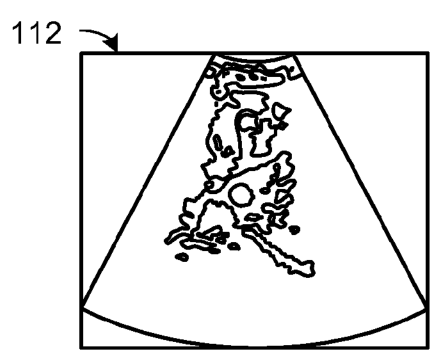


FIG. 16

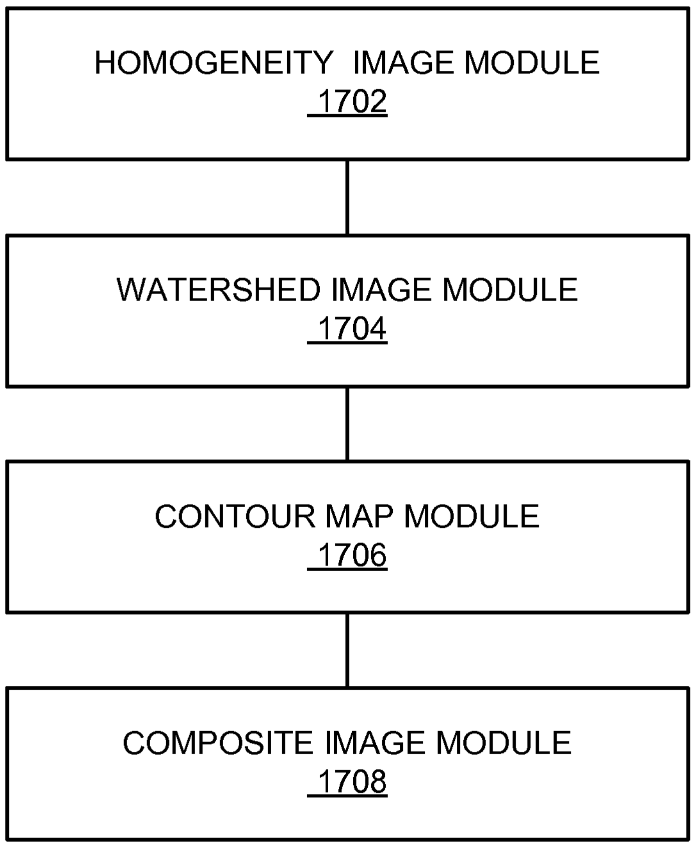

HOMOGENEITY IMAGE MODULE
1702
WATERSHED IMAGE MODULE
1704
CONTOUR MAP MODULE
1706
COMPOSITE IMAGE MODULE
1708

FIG. 17

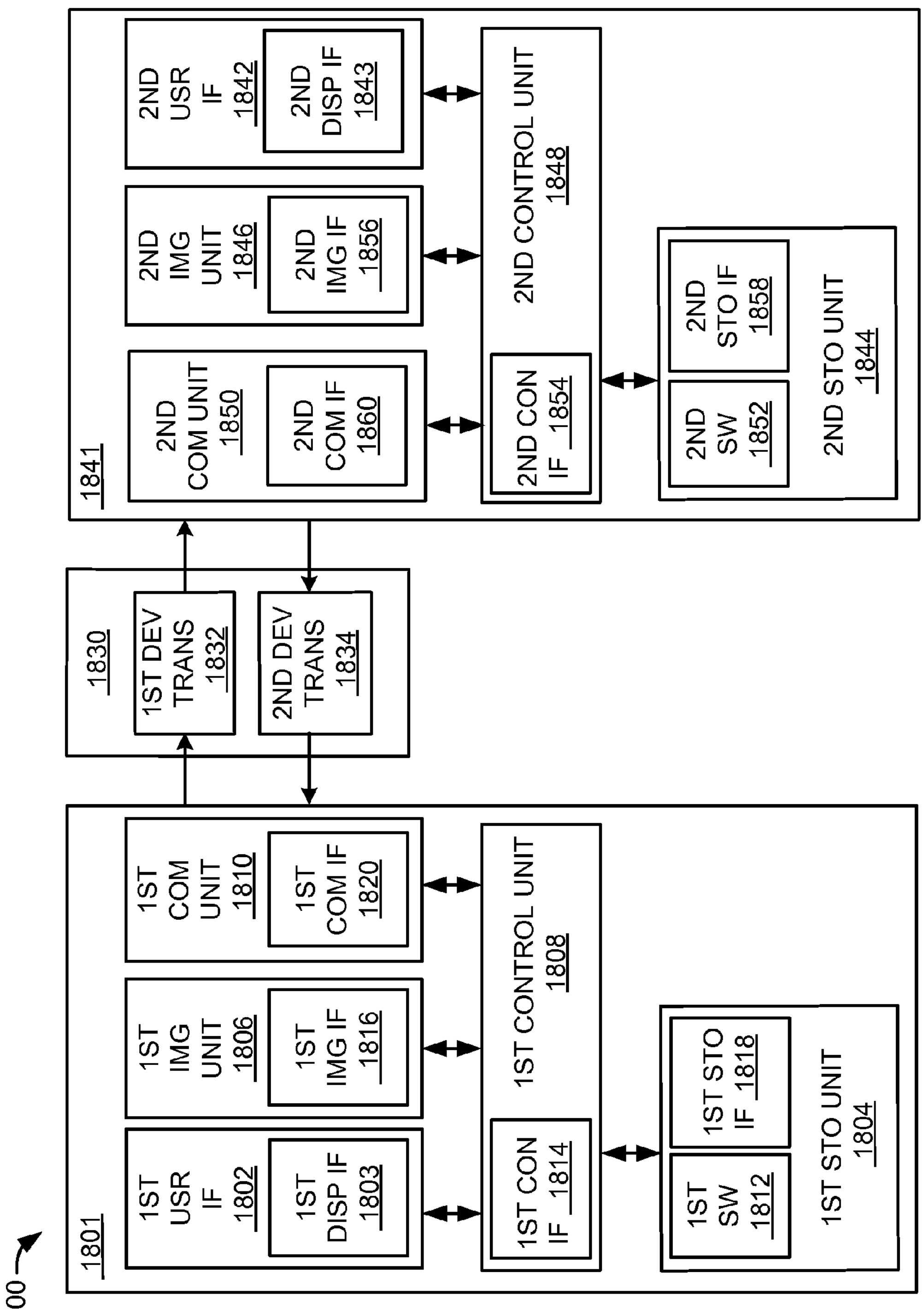

100
1801
1ST USR IF 1802
1ST DISP IF 1803
1ST IMG UNIT 1806
1ST IMG IF 1816
1ST COM UNIT 1810
1ST COM IF 1820
1ST CONTROL UNIT 1808
1ST CON IF 1814
1ST SW 1812
1ST STO IF 1818
1ST STO UNIT 1804
1830
1ST DEV TRANS 1832
2ND DEV TRANS 1834
1841
2ND COM UNIT 1850
2ND COM IF 1860
2ND IMG UNIT 1846
2ND IMG IF 1856
2ND USR IF 1842
2ND DISP IF 1843
2ND CONTROL UNIT 1848
2ND CON IF 1854
2ND SW 1852
2ND STO IF 1858
2ND STO UNIT 1844

FIG. 18

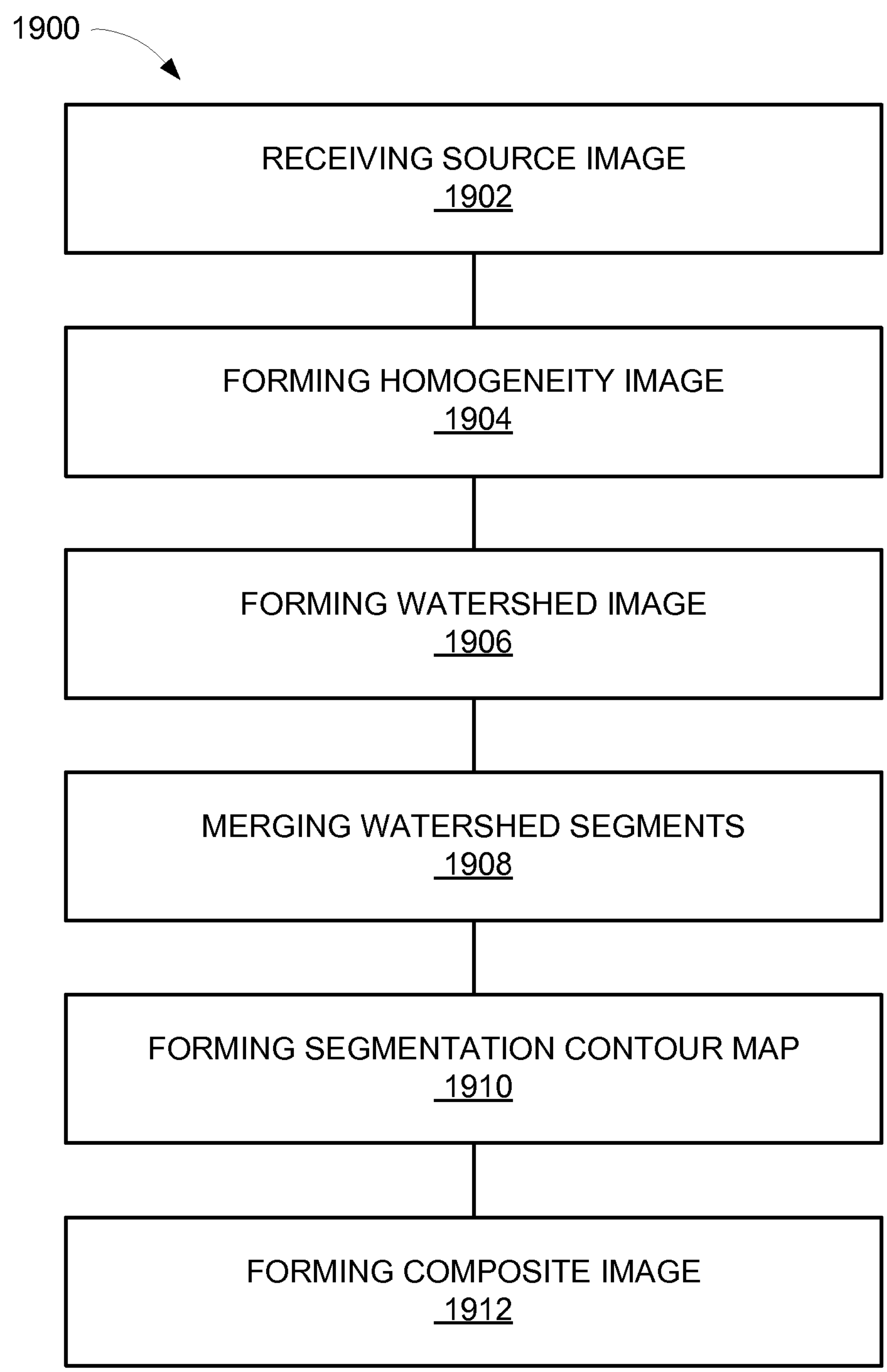

1900
RECEIVING SOURCE IMAGE
1902
FORMING HOMOGENEITY IMAGE
1904
FORMING WATERSHED IMAGE
1906
MERGING WATERSHED SEGMENTS
1908
FORMING SEGMENTATION CONTOUR MAP
1910
FORMING COMPOSITE IMAGE
1912

FIG. 19

IMAGE PROCESSING SYSTEM WITH AUTOMATIC SEGMENTATION AND METHOD OF OPERATION THEREOF

TECHNICAL FIELD

The present invention relates generally to image processing systems, and more particularly to an image processing system with automatic segmentation.

BACKGROUND ART

The deployment of high quality imaging to medical devices, smart phones, tablet computers, and other information devices with screens has grown tremendously in recent years. The wide variety of information devices supporting image processing and image understanding requires the ability to process multiple types of images with varying degrees of available information.

Medical imaging devices can provide diagnostic images based on different types of sensor information. Some medical imaging systems can display raw or dynamic imaging and video information in real time. Such systems can process image information of varying quality, resolution, and orientation, but still require a high degree of medical expertise to be interpreted properly to help reach an accurate diagnosis of a medical condition.

Other imaging systems can use ultrasound, x-ray, visible light, infrared, sound navigation and ranging (sonar), magnetic resonance imaging, positron emission tomography, or a combination thereof to generate static and dynamic images. Some systems require a priori information about the classes of images being analyzed. Other systems may require manual identification of initial control points to perform segmentation.

Thus, a need still remains for an image processing system that can create good quality images that are easier to interpret. Such images must be provided across a wide range of devices having different sizes, resolutions, memory capacity, compute power, and image quality. In view of the increasing demand for providing diagnostic medical imaging on the growing spectrum of intelligent imaging devices, it is increasingly critical that answers be found to these problems. In view of the ever-increasing commercial competitive pressures, along with growing consumer expectations and the diminishing opportunities for meaningful product differentiation in the marketplace, it is critical that answers be found for these problems. Additionally, the need to save costs, improve efficiencies and performance, and meet competitive pressures, adds an even greater urgency to the critical necessity for finding answers to these problems.

Solutions to these problems have long been sought but prior developments have not taught or suggested any solutions and, thus, solutions to these problems have long eluded those skilled in the art.

DISCLOSURE OF THE INVENTION

The present invention provides a method of operation of an image processing system including: receiving a source image having source pixels; forming a homogeneity image having homogeneity pixels each with a homogeneity value indicating the local homogeneity of source pixels of the source image; forming a watershed image by segmenting the homogeneity image, the watershed image having watershed segments with a segment weight; merging one of the watershed segments with another of the watershed segments with both of the watershed segments having the segment weight less than or equal to a segment threshold; forming a segmentation contour map having the boundaries of the watershed segments formed by merging the watershed segments; and forming a composite image with the segmentation contour map overlaying the source image for display on a device.

The present invention provides an image processing system including: a source image having source pixels; a homogeneity image module for forming a homogeneity image having homogeneity pixels each with a homogeneity value indicating the local homogeneity of source pixels of the source image; a watershed image module, coupled to the homogeneity image module, for forming a watershed image having watershed segments with a segment weight, the watershed image formed by segmenting the homogeneity image, and for merging one of the watershed segments with another of the watershed segments both having the segment weight less than or equal to a segment threshold; a contour map module, coupled to the watershed image module, for forming a segmentation contour map having boundaries of the watershed segments formed by merging the watershed segments; and a composite image module for forming a composite image with the segmentation contour map overlaying the source image for display on a device.

Certain embodiments of the invention have other aspects in addition to or in place of those mentioned above. The aspects will become apparent to those skilled in the art from a reading of the following detailed description when taken with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an image processing system in an embodiment of the present invention.

FIG. **2** is an example of the source image.

FIG. **3** is an example of a homogeneity image.

FIG. **4** is an example of the homogeneity measurement.

FIG. **5** is a first example of calculating the target vectors.

FIG. **6** is a second example of calculating the target vectors.

FIG. **7** is a third example of calculating the target vectors.

FIG. **8** is a fourth example of calculating the target vectors.

FIG. **9** is a fifth example of calculating the target vectors.

FIG. **10** is an example of a watershed image.

FIG. **11** is an example of hierarchical merging.

FIG. **12** is an example of an expanded view of the segment weight map.

FIG. **13** is an example of a homogeneity field with an expanded view.

FIG. **14** is an example of boundary direction approximation.

FIG. **15** is an example of the segmentation contour map.

FIG. **16** is an example of the composite image.

FIG. **17** is a process flow of the image processing system.

FIG. **18** is an example of a functional block diagram of the image processing system.

FIG. **19** is a flow chart of a method of operation of the image processing system in a further embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

The following embodiments are described in sufficient detail to enable those skilled in the art to make and use the invention. It is to be understood that other embodiments would be evident based on the present disclosure, and that process or mechanical changes may be made without departing from the scope of the present invention.

In the following description, numerous specific details are given to provide a thorough understanding of the invention. However, it will be apparent that the invention may be practiced without these specific details. In order to avoid obscuring the present invention, some well-known circuits, system configurations, and process steps are not disclosed in detail.

Likewise, the drawings showing embodiments of the system are semi-diagrammatic and not to scale and, particularly, some of the dimensions are for the clarity of presentation and are shown greatly exaggerated in the drawing FIGS. Where multiple embodiments are disclosed and described, having some features in common, for clarity and ease of illustration, description, and comprehension thereof, similar and like features one to another will ordinarily be described with like reference numerals.

The term "module" referred to herein can include software, hardware, or a combination thereof in the present invention in accordance with the context used. The term "adjacent" means two or more elements are next to one another.

The term "connected" means that two or more pixels or segments are next to one another with no intervening elements. The term "directly connected" means that two or more pixels or segments are in direct contact with one another with no intervening elements.

Referring now to FIG. **1**, therein is shown a block diagram of an image processing system **100** in an embodiment of the present invention. The image processing system **100** can receive a source image **108** in an image processing device **102** and generate a composite image **112** having a segmentation contour map **110** for display on a display device **104**. The image processing device **102** can be coupled to the display device **104** with a communication path **106**.

The source image **108** is a picture with varying intensity. The source image **108** can be color, monochromatic, or a combination thereof. For example, the source image **108** can be a medical image, a B-mode ultrasound image, an x-ray image, a visible light image, a sonar image, an infrared image, a computer axial tomography image, a magnetic resonance image, or a combination thereof.

The segmentation contour map **110** is a picture indicating the borders between regions representing different objects in the source image **108**. The segmentation contour map **110** can be a bitmap, a vector image, or a combination thereof. The segmentation contour map **110** can indicate the variation in intensity between different regions.

The segmentation contour map **110** can be formed without manual initialization. The auto-segmentation of the source image **108** to form the segmentation contour map **110** can be unsupervised and does not require a priori information about the type of images. The segmentation contour map **110** can be calculated using only the information within the source image **108** and does not use initialization input or prior information about the structure of the source image **108**. The segmentation contour map **110** can determine the classes outlined by the segmentation contour map **110**.

The segmentation contour map **110** can highlight the boundaries of objects represented in the source image **108**. For example, the source image **108** can be an ultrasound image with the segmentation contour map **110** indicating the head and body areas of a child. In another example, the source image **108** can be a chest x-ray image and the segmentation contour map **110** can indicate the location and outline of bones and organs.

The segmentation contour map **110** can be combined with the source image **108** to form the composite image **112**. The composite image **112** can include the contours overlaid on the source image **108** to highlight and illustrate the underlying elements in the source image **108**.

The image processing device **102** is an electrical component for receiving the source image **108**. The image processing device **102** can be an ultrasound machine, an x-ray machine, a digital camera, sonar system, video imaging system, or similar device. The image processing device **102** can include a computing device that can receive the source image **108** from a storage device, a network device, or a combination thereof.

The display device **104** is an electrical component for displaying information. For example, the display device **104** can include a monitor, video display, printer, or a combination thereof.

Although the image processing device **102** and the display device **104** are presented as two separate devices, it is understood that the image processing device **102** and the display device **104** can be implemented as a single device. For example, the image processing device **102** can include an integral monitor performing as the display device **104**.

Referring now to FIG. **2** therein is shown an example of the source image **108**. The source image **108** is a picture having source pixels **202**. The source pixels **202** are individual graphical elements. The source pixels **202** can have characteristics including a source pixel location **204** and a source pixel intensity **208**. For example, the source image **108** can be an ultrasound image.

The source image **108** can be provided in a variety of ways. For example, the source image **108** can be directly formed by imaging sensors of the image processing device **102** of FIG. **1**. In another example, the source image **108** can be received from a remote system via a file storage device, a network connection, or a combination thereof.

Referring now to FIG. **3**, therein is shown an example of a homogeneity image **302**. The homogeneity image **302** is a digital image derived from the source image **108** of FIG. **1**. The homogeneity image **302** can represent the variation in the local homogeneity of the source pixels **202** of FIG. **2** in the source image **108**.

The homogeneity image **302** includes homogeneity pixels **304**, each corresponding to the homogeneity of one of the source pixels **202** in the corresponding location in the source image **108**. The homogeneity pixels **304** can have characteristics such as a homogeneity pixel location **306** and a homogeneity pixel intensity **310**.

Referring now to FIG. **4**, therein is shown an example of the homogeneity measurement. The homogeneity image **302** of FIG. **3** can be calculated by measuring the level of homogeneity of each of the source pixels **202** in the source image **108** of FIG. **1**.

A local window **402** is determined for each of the source pixels **202** in the source image **108**. The local window **402** is the set of N×N neighboring pixels around a target pixel **412** where the target pixel **412** is one of the source pixels **202** in the source image **108**.

The local window **402** can have a window size **404**. The window size **404** is the number of pixels within the local window **402**. For example, the window size **404** can have a value of 3×3, 4×4, 5×5, or a similar value.

The target pixel **412** can have a homogeneity vector **406**. The homogeneity vector **406** can indicate the degree of homogeneity of the target pixel **412** based on the intensity and location of the source pixels **202** in the local window **402**.

The target pixel **412** can have target vectors **414** from the target pixel **412** to each of the source pixels **202** in the local window **402**. Each of the target vectors **414** can include a target vector direction **410** and a target vector magnitude **418**. The target vector direction **410** is the angle of one of the target vectors **414** measured from the right horizontal direction. The target vector magnitude **418** is the difference of the source pixel intensity **208** of FIG. **2** for one of the source pixels **202** in the local window **402** and that of the target pixel **412**.

The homogeneity vector **406** has a homogeneity value **408** and a homogeneity direction **416**. The homogeneity value **408** is the magnitude of the sum of all of the target vectors **414** for the target pixel **412**. The homogeneity direction **416** is the angle of the sum of all of the target vectors **414** for the target pixel **412**.

The homogeneity value **408** can be determined by constructing the target vectors **414** from the target pixel **412** to each of the source pixels **202** in the local window **402** and calculating the magnitude of the sum of all of the target vectors **414**. The homogeneity value **408** can be the magnitude of the sum of all of the target vectors **414**.

For example, the homogeneity vector **406** can be determined from the sum of the target vectors **414** from the target pixel **412** to the source pixels **202** at the upper right, right, and lower right ones of in the local window **402**. The homogeneity value **408** can be the magnitude of the target vectors **414**.

It has been discovered that using the homogeneity image **302** to calculate the segmentation contour map **110** of FIG. **1** can improve performance and simplify execution. The homogeneity image **302** is not sensitive to graphical irregularities, noise and results in a more accurate representation of the boundaries between regions.

Referring now to FIG. **5**, therein is shown a first example of calculating the target vectors **414** of FIG. **4**. The local window **402** can include a 5×5 array of the source pixels **202** around the target pixel **412**.

Each of the source pixels **202** in the local window **402** have the same value of the source pixel intensity **208** of FIG. **2** and an uniform distribution around the target pixel **412**, so the target vectors **414** will have an undefined or zero direction and the target vector magnitude **418** of FIG. **4** a value of zero. The homogeneity value **408** of FIG. **4** is zero.

Referring now to FIG. **6**, therein is shown a second example of calculating the target vectors **414**. The local window **402** can include a 5×5 array of the source pixels **202** around the target pixel **412**. The source pixels **202** in the local window **402** in the first, third, and fifth columns have the same value of the source pixel intensity **208** of FIG. **2**. The source pixels **202** in the local window **402** in the second and fourth columns have the source pixel intensity **208** of zero. The source pixels **202** provide even horizontal distribution on either side of the target pixel **412**, so the sum of the target vectors **414** will have an undefined or zero direction and the target vector magnitude **418** of FIG. **4** of zero. The homogeneity value **408** of FIG. **4** is zero.

Referring now to FIG. **7**, therein is shown a third example of calculating the target vectors **414**. The local window **402** can include a 5×5 array of the source pixels **202** around the target pixel **412**. The source pixels **202** in the local window **402** have a value of one or zero in an alternating distribution for each of the columns. The source pixels **202** provide a uniform distribution on all sides of the target pixel **412**, so the sum of the target vectors **414** will have an undefined or zero direction and the target vector magnitude **418** of FIG. **4** of zero. The homogeneity value **408** of FIG. **4** is zero.

Referring now to FIG. **8**, therein is shown a fourth example of calculating the target vectors **414**. The local window **402** can include a 5×5 array of the source pixels **202** around the target pixel **412**. The source pixels **202** in the local window **402** in the first, second, third, and fourth columns have the same value of one for the source pixel intensity **208** of FIG. **2**. The source pixels **202** in the local window **402** in the fifth column have the source pixel intensity **208** of zero. The arrangement of the source pixels **202** can represent the target pixel **412** near a border between two regions in the source image **108** of FIG. **1**.

The source pixels **202** provide a uniform vertical distribution, but have an unbalanced horizontal distribution. Calculating the target vectors **414** from the target pixel **412** to each of the other pixels in the local window **402** and summing the result provides a homogeneity value of 4.2 d, where d is the distance between pixels in the source image **108**. The sum of the target vectors **414** will have the target vector direction **410** of FIG. **4** of zero degrees based on the uniform vertical distribution of the pixel values.

Referring now to FIG. **9**, therein is shown a fifth example of calculating the target vectors **414**. The local window **402** can include a 5×5 array of the source pixels **202** around the target pixel **412**. The source pixels **202** in the local window **402** in the first, second, and third columns have the same value of one for the source pixel intensity **208** of FIG. **2**. The source pixels **202** in the local window **402** in the fourth and fifth columns have the source pixel intensity **208** of zero. The arrangement of the source pixels **202** can represent the target pixel **412** at a border between two regions in the source image **108** of FIG. **1**.

The source pixels **202** provide a uniform vertical distribution, but have an unbalanced horizontal distribution. Calculating the target vectors **414** from the target pixel **412** to each of the other pixels in the local window **402** and summing the result provides a homogeneity value of 47.5 d, where d is the distance between pixels in the source image **108**. The sum of the target vectors **414** will have the target vector direction **410** of FIG. **4** of zero degrees based on the uniform vertical distribution of the pixel values.

Referring now to FIG. **10**, therein is shown an example of a watershed image **1002**. The watershed image **1002** is a picture having watershed segments **1004** representing the variation in the homogeneity image **302** of FIG. **3**. The watershed image **1002** can be an image with segments based on the intensity variation of the homogeneity pixels **304** of FIG. **3**. The watershed image **1002** is formed by segmenting the homogeneity image **302**.

The watershed segments **1004** can have a watershed contour angle **1006**. The watershed contour angle **1006** is the angle of the line best-fit through one of the watershed segments **1004**.

The watershed image **1002** can be calculated in a variety of ways. The watershed image **1002** can be formed using a watershed segmentation technique. For example, the watershed image **1002** can be calculated using marker based transformations, local minima methods, a flooding algorithm, optimal spanning forest algorithms, or a combination thereof. In another example, the watershed image **1002** can be formed using other segmentation techniques.

The watershed segments **1004** can represent the boundaries between regions in the homogeneity image **302**. The values of the homogeneity pixels **304** in the homogeneity image **302** can represent a topological relief surface. A watershed threshold **1008** representing a horizontal plane can partition the relief surface into catchment basins below the watershed threshold **1008** and ridges above the watershed threshold **1008**. The watershed threshold **1008** can be varied to identify the watershed segments **1004** representing the ridges above the watershed threshold **1008**.

It has been discovered that using the homogeneity image **302** to calculate the watershed segments **1004** can improve performance and simplify execution. The homogeneity image **302** is not sensitive to graphical irregularities, noise and results in a more accurate representation of the boundaries between regions.

Referring now to FIG. **11**, therein is shown an example of hierarchical merging. The hierarchical merging process can assigned a segment weight **1102** to each of the watershed segments **1004** of FIG. **10** based on the homogeneity image **302** of FIG. **3** and then hierarchically merge small segments based on the segment weight **1102** to form a single one of the watershed segments **1004**. The watershed segments **1004** are structural elements separating regions representing objects in the homogeneity image **302**.

The segment weight **1102** is a value indicating the directionality of the homogeneity vector **406** of FIG. **4** for one of the homogeneity pixels **304** of FIG. **3** in the homogeneity image **302**. For example, the segment weight **1102** can be the directional component of the homogeneity value **408** of FIG. **4** in the direction of each of the watershed segments **1004** calculated by projecting the homogeneity vector **406** onto the direction of the boundary of each of the watershed segments **1004**. Small values of the homogeneity value **408** indicate a homogeneous region, while larger values of the homogeneity value **408** indicate an inhomogeneous region.

The segment weight **1102** is smaller if the homogeneity value **408** in the homogeneity image **302** is small along the contour of one of the watershed segments **1004**. The segment weight **1102** can have a larger weight if the homogeneity value **408** in the homogeneity image **302** is larger along the contour of one of the watershed segments **1004**. The watershed segments **1004** represent a group of pixels.

The watershed segments **1004** can be hierarchically merged based on the segment weight **1102** of the boundary of each of the watershed segments **1004**. The watershed segments **1004** can be merged in the order of segment weight with the watershed segments **1004** having smaller values of the segment weight **1102** merged first. The merge process can stop when the segment weight **1102** of the watershed segments **1004** is above a segment threshold **1106**.

The segment threshold **1106** is a value indicating the minimum weight of one of the watershed segments **1004** likely to represent a boundary. The segment threshold **1106** can be pre-determined, dynamically calculated based on the characteristics of the homogeneity image **302**, or a combination thereof. For example, the segment threshold **1106** can be calculated using the segmentation output of a graph cut process. The segment threshold **1106** can be adjusted to merge together the watershed segments **1004** caused by graphical irregularities in the homogeneity image **302**.

The graph-cut process can final a globally optimal segmentation solution. A graph can be partitioned into two disjoint sets by removing edges connecting the two parts. The segmentation contour map **110** of FIG. **1** can be partitioned by removing one of the watershed segments **1004** in the watershed image **1002** before forming the segmentation contour map **110**.

The group-cut results provide the boundaries of the two disjoint sets of image pixels. First, collect the weights of the boundaries of the watershed segments that are most close to the boundaries of the two disjoint sets of image pixels. Then set the median value of the collected weights as the segment threshold.

Two of the watershed segments **1004** that are directly connected to one another with no intervening elements and both have the segment weight **1102** less than or equal to the segment threshold **1106** can be merged together. For example, merging two of the watershed segments **1004** can be performed by assigning all of the pixels of one of the watershed segments **1004** to the other one of the watershed segments **1004**.

The hierarchically connected segments can be used to form the segmentation contour map **110**. The segmentation contour map **110** can indicate the edges of regions within the source image **108** of FIG. **1**. Different values for the segment threshold **1106** can result in different merging results for the segmentation contour map **110**. The segmentation contour map **110** can be threshold to optimize the final result by changing the value of the segment threshold **1106**. The boundary between two segments is removed and the two segments become connected. The merge process is hierarchical because two small segments produced by the watershed process are merged to form a larger segment, and the larger segment can be merged with another segment to form a still larger segment.

It has been discovered that merging the watershed segments **1004** with weak boundaries having the segment weight **1102** less than the segment threshold **1106** can increase performance by eliminating the need to determine the number of classes. By merging the watershed segments **1004** having small values of the homogeneity value **408**, the weak boundaries can be eliminated while preserving the strong boundaries between regions.

It has been discovered that hierarchically merging the watershed segments **1004** calculated based on the homogeneity image **302** can increase performance by auto-segmenting general images without supervision. The automated process of merging the watershed segments **1004** based on the segment threshold **1106** allows faster, unsupervised determination of the segmentation contour map **110**.

Referring now to FIG. **12**, therein is shown an example of an expanded view **1202** of the segment weight map. The segment weight map can show the segment weights if only using the pixel values of the homogeneity image **302**. The expanded view **1202** shows details of the segment weights if only using the pixel values of the homogeneity image **302**. The expanded view **1202** shows that the variations in the homogeneity image **302** can generate artifacts. Compensating for the artifacts can be done by taking into consideration how well the boundary norm direction is aligned with the direction of the homogeneity vectors forming the homogeneity field of the homogeneity image **302**.

Referring now to FIG. **13**, therein is shown an example of a homogeneity field **1302** with an expanded view **1304**. The homogeneity field **1302** is vector field formed by the homogeneity image **302** of FIG. **3**. The homogeneity direction **416** of FIG. **4** of the target pixel **412** of FIG. **4** can be measured against the norm for a boundary direction to reduce the number of artifacts. The homogeneity field **1302** can be the aggregation of the homogeneity value **408** of FIG. **4** and the homogeneity direction **416** of FIG. **4** for the homogeneity vector **406** of FIG. **4** of each of the homogeneity pixels **304** of FIG. **3**.

Referring now to FIG. **14**, therein is shown an example of segment boundary direction approximation. The boundaries of the watershed segments **1004** can be approximated with straight line segments **1104**. The directions of the straight line segments **1104** are straight line approximations of the direction of the boundaries of watershed segments **1004**.

Referring now to FIG. **15**, therein is shown an example of the segmentation contour map **110**. The segmentation contour map **110** can indicate the boundaries of objects representing in the source image **108** of FIG. **1**. The segmentation contour map **110** can show the contour lines between different regions within the source image **108**.

Referring now to FIG. **16**, therein is shown an example of the composite image **112**. The composite image **112** shows the segmentation contour map **110** of FIG. **1** overlaid on the source image **108** of FIG. **1** show highlight the boundaries of different regions. For example, the composite image **112** can outline the boundaries between heads, arms, and legs in an ultrasound image.

Referring now to FIG. **17**, therein is shown a process flow for the image processing system **100** of FIG. **1**. The image processing system **100** can process the source image **108** of FIG. **1** and display the composite image **112** of FIG. **1** having the segmentation contour map **110** of FIG. **1** on the display device **104** of FIG. **1**. The image processing system **100** can include a homogeneity image module **1702**, a watershed image module **1704**, a contour map module **1706**, and a composite image module **1708**.

The homogeneity image module **1702** can form the homogeneity image **302** of FIG. **3** from the source image **108**. Each of the source pixels **202** of FIG. **2** in the source image **108** can have a corresponding one of the homogeneity pixels **304** of FIG. **3** in the homogeneity image **302**.

The homogeneity image module **1702** can calculate the homogeneity vector **406** of FIG. **4** for each of the source pixels **202** in the source image **108**. The homogeneity value **408** of FIG. **4** associated with the homogeneity vector **406** can be used to set the associated value of the homogeneity pixels **304** in the homogeneity image **302** for the corresponding one of the source pixels **202**.

The homogeneity image module **1702** can calculate the local window **402** of FIG. **4** for each of the source pixels **202** in the source image **108**. The window size **404** of FIG. **4** can be set dynamically, pre-determined, based on image classification, or a combination thereof.

Each of the source pixels **202** can be designated as the target pixel **412** of FIG. **4**. The target pixel **412** of FIG. **4** can be determined by iterating over all of the source pixels **202** in the source image **108**.

The local window **402** is an N×N array centered on the target pixel **412** where N is the window size **404**. The homogeneity image module **1702** can calculate the set of the target vectors **414** of FIG. **4** from the target pixel **412** to each of the source pixels **202** in the local window **402**. Each of the source pixels **202** can have (N×N)−1 of the target vectors **414** associated with the target pixel **412**.

The homogeneity image module **1702** can calculate the homogeneity vector **406** for the target pixel **412** based on the target vectors **414**. The homogeneity vector **406** can indicate the degree of homogeneity of the target pixel **412** based on the intensity and location of the source pixels **202** in the local window **402**. The homogeneity vector **406** is calculated based on the sum of all of the target vectors **414** in the local window **402**.

The homogeneity vector **406** has the homogeneity value **408** and the homogeneity direction **416** of FIG. **4**. The homogeneity value **408** is the magnitude of the sum of all of the target vectors **414** for the target pixel **412**. The homogeneity direction **416** is the angle of the sum of all of the target vectors **414** for the target pixel **412**.

The homogeneity value **408** can be the magnitude of the sum of all of the set of the target vectors **414**. The homogeneity value **408** can indicate the local homogeneity of the source image **108**.

The homogeneity image **302** is formed by calculating the homogeneity value **408** for the homogeneity pixels **304**. Each of the homogeneity pixels **304** can be assigned the homogeneity value **408** of the target pixel **412** at the corresponding location in the homogeneity image **302**.

After the homogeneity image module **1702** calculates the homogeneity image **302**, the control flow can pass to the watershed image module **1704**.

The watershed image module **1704** can form the watershed image **1002** of FIG. **10** based on the homogeneity image **302**. The watershed image **1002** can be calculated using a watershed segmentation technique. The watershed image **1002** can include the watershed segments **1004** of FIG. **10** partitioning the regions of the homogeneity image **302** based on the intensity of the homogeneity pixels **304** in the homogeneity image **302**.

The watershed image module **1704** can apply the watershed segmentation process to generate the watershed segments **1004** representing the boundary between regions in the homogeneity image **302**. The watershed segments **1004** can indicate boundaries having similar values for the homogeneity value **408** of the homogeneity pixels **304** in the homogeneity image **302**. For example, the watershed segments **1004** act like the ridges between catchment basin regions having similar properties.

The watershed segmentation process can be sensitive to noise and other image irregularities in the homogeneity image **302**. Calculating the watershed image **1002** can result in over-segmentation where an excess of the watershed segments **1004** are detected due to the image irregularities such as noise, pixel variations, shadows, or a combination thereof.

The overabundance of the watershed segments **1004** can make it difficult to detect the underlying objects represented in the source image **108**. Each of the local regional minimums within the homogeneity image **302** can be segmented. For example, each of the pixels representing noise or small irregularities can be surrounded by the watershed segments **1004**.

To reduce the overabundance of the watershed segments **1004**, the watershed image module **1704** can perform a hierarchical merging process to merge the watershed segments **1004** that are connected to one another. The watershed segments **1004** can be merged together into a single large one of the watershed segments **1004** to reduce the level of segmentation.

The boundary of each of the watershed segments **1004** can have the segment weight **1102** of FIG. **11** assigned based on the directionality of the homogeneity value **408** of the homogeneity pixels **304** at that location. Then the watershed segments **1004** can be hierarchically merged small segments based on the segment weight **1102** being less than the segment threshold **1106** of FIG. **11**. The segment threshold **1106** can be pre-determined, calculated dynamically, or a combination thereof.

The segment weight **1102** can be calculated by determining the directionality of the homogeneity vector **406** for one of the homogeneity pixels **304** in the homogeneity image **302**. The segment weight **1102** is smaller if the homogeneity value **408** in the homogeneity image **302** is small along the contour of one of the watershed segments **1004**. The segment weight **1102** can have a larger weight if the homogeneity value **408** in the homogeneity image **302** is larger along the contour of one of the watershed segments **1004**.

The watershed image module **1704** can merge two of the watershed segments **1004** that are connected to one another and both have the segment weight **1102** below the segment threshold **1106**. The values for the segment threshold **1106** can vary and result in different merging results for the watershed segments **1004**. The merger process can iterate over all of the watershed segments **1004** to reduce the number of segments and form the boundaries around larger regions in the homogeneity image **302**. After the watershed image **1002** has been formed and the watershed segments **1004** merged to reduce the level of over-segmentation, the control flow can pass to the contour map module **1706**.

It has been discovered that merging the watershed segments **1004** based on the segment weight **1102** can increase the accuracy of the segmentation contour map **110**. Growing the regions by merging the watershed segments **1004** groups together similar adjacent regions.

The contour map module **1706** can form the segmentation contour map **110** by merging the watershed segments **1004** based on their segment weights. The segment weight is determined by the homogeneity value **408**, the direction of homogeneity vector **406** and the directions of boundaries of watershed segments **1004**. The straight line segments **1104** are line segments that approximate the boundaries of the watershed segments **1004**. The straight line segments **1104** can be calculated by determining the parameters of lines through the ends of one of the watershed segments **1004**. The set of the boundaries of the segments after merging can then be used to form the segmentation contour map **110**. The segmentation contour map **110** can indicate the edges of regions representing object within the source image **108**. After forming the segmentation contour map **110**, the control flow can pass to the composite image module **1708**.

The composite image module **1708** can combine the segmentation contour map **110** and the source image **108** to highlight the regions in the source image **108** representing object of interest. The segmentation contour map **110** can be overlaid on the source image **108**. The composite image **112** can be displayed on the display device **104**.

Referring now to FIG. **18**, therein is shown an example of a functional block diagram of the image processing system **100**. The image processing system **100** can include a first device **1801**, a second device **1841** and a communication link **1830**.

The image processing system **100** can be implemented using the first device **1801**, the second device **1841**, and the communication link **1830**. For example, the first device **1801** can implement the image processing device **102** of FIG. **1**, the second device **1841** can implement the display device **104** of FIG. **1**. And the communication link **1830** can implement the communication path **106** of FIG. **1**. However, it is understood that the image processing system **100** can be implemented in a variety of ways and the functionality of the image processing device **102**, the display device **104**, and the communication path **106** can be partitioned differently over the first device **1801**, the second device **1841**, and the communication link **1830**.

The first device **1801** can communicate with the second device **1841** over the communication link **1830**. The first device **1801** can send information in a first device transmission **1832** over the communication link **1830** to the second device **1841**. The second device **1841** can send information in a second device transmission **1834** over the communication link **1830** to the first device **1801**.

For illustrative purposes, the image processing system **100** is shown with the first device **1801** as a client device, although it is understood that the image processing system **100** can have the first device **1801** as a different type of device. For example, the first device can be a server.

Also for illustrative purposes, the image processing system **100** is shown with the second device **1841** as a server, although it is understood that the image processing system **100** can have the second device **1841** as a different type of device. For example, the second device **1841** can be a client device.

For brevity of description in this embodiment of the present invention, the first device **1801** will be described as a client device, such as a video camera, smart phone, or a combination thereof. The present invention is not limited to this selection for the type of devices. The selection is an example of the present invention.

The first device **1801** can include a first control unit **1808**. The first control unit **1808** can include a first control interface **1814**. The first control unit **1808** can execute a first software **1812** to provide the intelligence of the image processing system **100**.

The first control unit **1808** can be implemented in a number of different manners. For example, the first control unit **1808** can be a processor, an embedded processor, a microprocessor, a hardware control logic, a hardware finite state machine (FSM), a digital signal processor (DSP), or a combination thereof.

The first control interface **1814** can be used for communication between the first control unit **1808** and other functional units in the first device **1801**. The first control interface **1814** can also be used for communication that is external to the first device **1801**.

The first control interface **1814** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the first device **1801**.

The first control interface **1814** can be implemented in different ways and can include different implementations depending on which functional units or external units are being interfaced with the first control interface **1814**. For example, the first control interface **1814** can be implemented with electrical circuitry, microelectromechanical systems (MEMS), optical circuitry, wireless circuitry, wireline circuitry, or a combination thereof.

The first device **1801** can include a first storage unit **1804**. The first storage unit **1804** can store the first software **1812**. The first storage unit **1804** can also store the relevant information, such as images, syntax information, video, profiles, display preferences, sensor data, or any combination thereof.

The first storage unit **1804** can be a volatile memory, a nonvolatile memory, an internal memory, an external memory, or a combination thereof. For example, the first storage unit **1804** can be a nonvolatile storage such as nonvolatile random access memory (NVRAM), Flash memory, disk storage, or a volatile storage such as static random access memory (SRAM).

The first storage unit **1804** can include a first storage interface **1818**. The first storage interface **1818** can be used for communication between the first storage unit **1804** and other functional units in the first device **1801**. The first storage interface **1818** can also be used for communication that is external to the first device **1801**.

The first device **1801** can include a first imaging unit **1806**. The first imaging unit **1806** can capture the source image **108** of FIG. **1** from the real world. The first imaging unit **1806** can include a digital camera, a video camera, an optical sensor, or any combination thereof.

The first imaging unit **1806** can include a first imaging interface **1816**. The first imaging interface **1816** can be used for communication between the first imaging unit **1806** and other functional units in the first device **1801**.

The first imaging interface **1816** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the first device **1801**.

The first imaging interface **1816** can include different implementations depending on which functional units or external units are being interfaced with the first imaging unit **1806**. The first imaging interface **1816** can be implemented with technologies and techniques similar to the implementation of the first control interface **1814**.

The first storage interface **1818** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the first device **1801**.

The first storage interface **1818** can include different implementations depending on which functional units or external units are being interfaced with the first storage unit **1804**. The first storage interface **1818** can be implemented with technologies and techniques similar to the implementation of the first control interface **1814**.

The first device **1801** can include a first communication unit **1810**. The first communication unit **1810** can be for enabling external communication to and from the first device **1801**. For example, the first communication unit **1810** can permit the first device **1801** to communicate with the second device **1841**, an attachment, such as a peripheral device or a computer desktop, and the communication link **1830**.

The first communication unit **1810** can also function as a communication hub allowing the first device **1801** to function as part of the communication link **1830** and not limited to be an end point or terminal unit to the communication link **1830**. The first communication unit **1810** can include active and passive components, such as microelectronics or an antenna, for interaction with the communication link **1830**.

The first communication unit **1810** can include a first communication interface **1820**. The first communication interface **1820** can be used for communication between the first communication unit **1810** and other functional units in the first device **1801**. The first communication interface **1820** can receive information from the other functional units or can transmit information to the other functional units.

The first communication interface **1820** can include different implementations depending on which functional units are being interfaced with the first communication unit **1810**. The first communication interface **1820** can be implemented with technologies and techniques similar to the implementation of the first control interface **1814**.

The first device **1801** can include a first user interface **1802**. The first user interface **1802** allows a user (not shown) to interface and interact with the first device **1801**. The first user interface **1802** can include a first user input (not shown). The first user input can include touch screen, gestures, motion detection, buttons, slicers, knobs, virtual buttons, voice recognition controls, or any combination thereof.

The first user interface **1802** can include the first display interface **1803**. The first display interface **1803** can allow the user to interact with the first user interface **1802**. The first display interface **1803** can include a display, a video screen, a speaker, or any combination thereof.

The first control unit **1808** can operate with the first user interface **1802** to display image information generated by the image processing system **100** on the first display interface **1803**. The first control unit **1808** can also execute the first software **1812** for the other functions of the image processing system **100**, including receiving image information from the first storage unit **1804** for display on the first display interface **1803**. The first control unit **1808** can further execute the first software **1812** for interaction with the communication link **1830** via the first communication unit **1810**.

For illustrative purposes, the first device **1801** can be partitioned having the first user interface **1802**, the first storage unit **1804**, the first control unit **1808**, and the first communication unit **1810**, although it is understood that the first device **1801** can have a different partition. For example, the first software **1812** can be partitioned differently such that some or all of its function can be in the first control unit **1808** and the first communication unit **1810**. Also, the first device **1801** can include other functional units not shown in FIG. **17** for clarity.

The image processing system **100** can include the second device **1841**. The second device **1841** can be optimized for implementing the present invention in a multiple device embodiment with the first device **1801**. The second device **1841** can provide the additional or higher performance processing power compared to the first device **1801**.

The second device **1841** can include a second control unit **1848**. The second control unit **1848** can include a second control interface **1854**. The second control unit **1848** can execute a second software **1852** to provide the intelligence of the image processing system **100**.

The second control unit **1848** can be implemented in a number of different manners. For example, the second control unit **1848** can be a processor, an embedded processor, a microprocessor, a hardware control logic, a hardware finite state machine (FSM), a digital signal processor (DSP), or a combination thereof.

The second control interface **1854** can be used for communication between the second control unit **1848** and other functional units in the second device **1841**. The second control interface **1854** can also be used for communication that is external to the second device **1841**.

The second control interface **1854** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the second device **1841**.

The second control interface **1854** can be implemented in different ways and can include different implementations depending on which functional units or external units are being interfaced with the second control interface **1854**. For example, the second control interface **1854** can be implemented with electrical circuitry, microelectromechanical systems (MEMS), optical circuitry, wireless circuitry, wireline circuitry, or a combination thereof.

The second device **1841** can include a second storage unit **1844**. The second storage unit **1844** can store the second software **1852**. The second storage unit **1844** can also store the relevant information, such as images, syntax information, video, profiles, display preferences, sensor data, or any combination thereof.

The second storage unit **1844** can be a volatile memory, a nonvolatile memory, an internal memory, an external memory, or a combination thereof. For example, the second storage unit **1844** can be a nonvolatile storage such as nonvolatile random access memory (NVRAM), Flash memory, disk storage, or a volatile storage such as static random access memory (SRAM).

The second storage unit **1844** can include a second storage interface **1858**. The second storage interface **1858** can be used for communication between the second storage unit **1844** and other functional units in the second device **1841**. The second storage interface **1858** can also be used for communication that is external to the second device **1841**.

The second storage interface **1858** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the second device **1841**.

The second storage interface **1858** can include different implementations depending on which functional units or external units are being interfaced with the second storage unit **1844**. The second storage interface **1858** can be implemented with technologies and techniques similar to the implementation of the second control interface **1854**.

The second device **1841** can include a second imaging unit **1846**. The second imaging unit **1846** can capture the source image **108** from the real world. The first imaging unit **1806** can include a digital camera, a video camera, an optical sensor, or any combination thereof.

The second imaging unit **1846** can include a second imaging interface **1856**. The second imaging interface **1856** can be used for communication between the second imaging unit **1846** and other functional units in the second device **1841**.

The second imaging interface **1856** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the second device **1841**.

The second imaging interface **1856** can include different implementations depending on which functional units or external units are being interfaced with the second imaging unit **1846**. The second imaging interface **1856** can be implemented with technologies and techniques similar to the implementation of the first control interface **1814**.

The second device **1841** can include a second communication unit **1850**. The second communication unit **1850** can enable external communication to and from the second device **1841**. For example, the second communication unit **1850** can permit the second device **1841** to communicate with the first device **1801**, an attachment, such as a peripheral device or a computer desktop, and the communication link **1830**.

The second communication unit **1850** can also function as a communication hub allowing the second device **1841** to function as part of the communication link **1830** and not limited to be an end point or terminal unit to the communication link **1830**. The second communication unit **1850** can include active and passive components, such as microelectronics or an antenna, for interaction with the communication link **1830**.

The second communication unit **1850** can include a second communication interface **1860**. The second communication interface **1860** can be used for communication between the second communication unit **1850** and other functional units in the second device **1841**. The second communication interface **1860** can receive information from the other functional units or can transmit information to the other functional units.

The second communication interface **1860** can include different implementations depending on which functional units are being interfaced with the second communication unit **1850**. The second communication interface **1860** can be implemented with technologies and techniques similar to the implementation of the second control interface **1854**.

The second device **1841** can include a second user interface **1842**. The second user interface **1842** allows a user (not shown) to interface and interact with the second device **1841**. The second user interface **1842** can include a second user input (not shown). The second user input can include touch screen, gestures, motion detection, buttons, slicers, knobs, virtual buttons, voice recognition controls, or any combination thereof.

The second user interface **1842** can include a second display interface **1843**. The second display interface **1843** can allow the user to interact with the second user interface **1842**. The second display interface **1843** can include a display, a video screen, a speaker, or any combination thereof.

The second control unit **1848** can operate with the second user interface **1842** to display information generated by the image processing system **100** on the second display interface **1843**. The second control unit **1848** can also execute the second software **1852** for the other functions of the image processing system **100**, including receiving display information from the second storage unit **1844** for display on the second display interface **1843**. The second control unit **1848** can further execute the second software **1852** for interaction with the communication link **1830** via the second communication unit **1850**.

For illustrative purposes, the second device **1841** can be partitioned having the second user interface **1842**, the second storage unit **1844**, the second control unit **1848**, and the second communication unit **1850**, although it is understood that the second device **1841** can have a different partition. For example, the second software **1852** can be partitioned differently such that some or all of its function can be in the second control unit **1848** and the second communication unit **1850**. Also, the second device **1841** can include other functional units not shown in FIG. **17** for clarity.

The first communication unit **1810** can couple with the communication link **1830** to send information to the second device **1841** in the first device transmission **1832**. The second device **1841** can receive information in the second communication unit **1850** from the first device transmission **1832** of the communication link **1830**.

The second communication unit **1850** can couple with the communication link **1830** to send image information to the first device **1801** in the second device transmission **1834**. The first device **1801** can receive image information in the first communication unit **1810** from the second device transmission **1834** of the communication link **1830**. The image processing system **100** can be executed by the first control unit **1808**, the second control unit **1848**, or a combination thereof.

The functional units in the first device **1801** can work individually and independently of the other functional units. For illustrative purposes, the image processing system **100** is described by operation of the first device **1801**. It is understood that the first device **1801** can operate any of the modules and functions of the image processing system **100**. For example, the first device **1801** can be described to operate the first control unit **1808**.

The functional units in the second device **1841** can work individually and independently of the other functional units. For illustrative purposes, the image processing system **100** can be described by operation of the second device **1841**. It is understood that the second device **1841** can operate any of the modules and functions of the image processing system **100**. For example, the second device **1841** is described to operate the second control unit **1848**.

For illustrative purposes, the image processing system **100** is described by operation of the first device **1801** and the second device **1841**. It is understood that the first device **1801** and the second device **1841** can operate any of the modules and functions of the image processing system **100**. For example, the first device **1801** is described to operate the first control unit **1808**, although it is understood that the second device **1841** can also operate the first control unit **1808**.

The physical transformation from the images of physical objects of the source image **108** to displaying the output text on the pixel elements of the display device **104** results in physical changes to the pixel elements of the display device **104** in the physical world, such as the change of electrical state the pixel element, is based on the operation of the image processing system **100**. As the changes in the physical world occurs, such as the motion of the imaging sensor used to capture the source image **108**, the movement itself creates additional information, such as the updates to the source image **108**, that are converted back into changes in the pixel elements of the display device **104** for continued operation of the image processing system **100**.

The first software **1812** of the first device **1801** can implement portions of the image processing system **100**. For example, the first software **1812** can include the homogeneity image module **1702** of FIG. **17**, the watershed image module **1704** of FIG. **17**, the contour map module **1706** of FIG. **17**, and the composite image module **1708** of FIG. **17**.

The first control unit **1808** can execute the first software **1812** for the homogeneity image module **1702** to form the homogeneity image **302** of FIG. **3** from the source image **108**. The first control unit **1808** can execute the first software **1812** for the watershed image module **1704** to form the watershed image **1002** of FIG. **10** from the homogeneity image **302**. The first control unit **1808** can execute the first software **1812** for the contour map module **1706** to form the segmentation contour map **110** of FIG. **1** from the watershed image **1002**. The first control unit **1808** can execute the first software **1812** for the composite image module **1708** to form the composite image **112** of FIG. **1** from the segmentation contour map **110** and the source image **108**.

The second software **1852** of the second device **1841** can implement portions of the image processing system **100**. For example, the second software **1852** can include the homogeneity image module **1702**, the watershed image module **1704**, the contour map module **1706**, and the composite image module **1708**.

The second control unit **1848** can execute the second software **1852** for the homogeneity image module **1702** to form the homogeneity image **302** of FIG. **3** from the source image **108**. The second control unit **1848** can execute the second software **1852** for the watershed image module **1704** to form the watershed image **1002** from the homogeneity image **302**. The second control unit **1848** can execute the second software **1852** for the contour map module **1706** to form the segmentation contour map **110** from the watershed image **1002**. The second control unit **1848** can execute the second software **1852** for the composite image module **1708** to form the composite image **112** from the segmentation contour map **110** and the source image **108**.

The image processing system **100** can be partitioned between the first software **1812** and the second software **1852**. For example, the first software **1812** can include the homogeneity image module **1702** and the watershed image module **1704** and the second software **1852** can include the contour map module **1706** and the composite image module **1708**. The first control unit **1808** can execute the modules partitioned to the first software **1812**. The second control unit **1848** can execute modules partitioned to the second software **1852**.

The first control unit **1808** can operate the first communication unit **1810** to send the source image **108** to the second device **1841**. The first control unit **1808** can operate the first software **1812** to operate the first imaging unit **1806**. The second communication unit **1850** can send the source image **108** to the first device **1801** over the communication link **1830**.

The image processing system **100** describes the module functions or order as an example. The modules can be partitioned differently. For example, the contour map module **1706** and the composite image module **1708** can be combined. Each of the modules can operate individually and independently of the other modules.

Furthermore, data generated in one module can be used by another module without being directly coupled to each other. For example, the composite image module **1708** can receive the source image **108** from the homogeneity image module **1702**.

The modules can be implemented in a variety of ways. The homogeneity image module **1702** and the watershed image module **1704** can be implemented in hardware accelerators (not shown) within the first control unit **1808** or the second control unit **1848**, or can be implemented in hardware accelerators (not shown) in the first device **1801** or the second device **1841** outside of the first control unit **1808** or the second control unit **1848**.

Referring now to FIG. **19**, therein is shown a flow chart of a method **1900** of operation of the image processing system in a further embodiment of the present invention. The method **1900** includes: receiving a source image having source pixels in a block **1902**; forming a homogeneity image having homogeneity pixels each with a homogeneity value indicating the local homogeneity of source pixels of the source image in a block **1904**; forming a watershed image by segmenting the homogeneity image, the watershed image having watershed segments with a segment weight in a block **1906**; merging one of the watershed segments with another of the watershed segments with both of the watershed segments having the segment weight less than or equal to a segment threshold in a block **1908**; forming a segmentation contour map having the boundaries of the watershed segments formed by merging the watershed segments in a block **1910**; and forming a composite image with the segmentation contour map overlaying the source image for display on a device in a block **1912**.

It has been discovered that the present invention thus has numerous aspects. The present invention valuably supports and services the historical trend of reducing costs, simplifying systems, and increasing performance. These and other valuable aspects of the present invention consequently further the state of the technology to at least the next level.

Thus, it has been discovered that the image processing system of the present invention furnishes important and heretofore unknown and unavailable solutions, capabilities, and functional aspects for efficiently auto-segmenting images. The resulting processes and configurations are straightforward, cost-effective, uncomplicated, highly versatile and effective, can be surprisingly and unobviously implemented by adapting known technologies, and are thus readily suited for efficiently and economically manufacturing image processing devices fully compatible with conventional manufacturing processes and technologies. The resulting processes and configurations are straightforward, cost-effective, uncomplicated, highly versatile, accurate, sensitive, and effective, and can be implemented by adapting known components for ready, efficient, and economical manufacturing, application, and utilization.

While the invention has been described in conjunction with a specific best mode, it is to be understood that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the aforegoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations that fall within the scope of the included claims. All matters hithertofore set forth herein or shown in the accompanying drawings are to be interpreted in an illustrative and non-limiting sense.

What is claimed is:

1. A method of operation of an image processing system comprising:

receiving a source image having source pixels;

forming a homogeneity image having homogeneity pixels each with a homogeneity value indicating the local homogeneity of source pixels of the source image;

forming a watershed image by segmenting the homogeneity image, the watershed image having watershed segments with a segment weight;

merging one of the watershed segments with another of the watershed segments with both of the watershed segments having the segment weight less than or equal to a segment threshold;

forming a segmentation contour map having the boundaries of the watershed segments formed by merging the watershed segments; and

forming a composite image with the segmentation contour map overlaying the source image for display on a device.

2. The method as claimed in claim **1** further comprising:

calculating target vectors having a target vector magnitude, the target vectors extending from a target pixel to each of the source pixels in a local window; and

calculating a homogeneity vector having the homogeneity value set to the norm of the sum of the target vector magnitude of all of the target vectors.

3. The method as claimed in claim **1** wherein forming the watershed image includes calculating the segment weight for one of the watershed segments based on the value of the homogeneity value along a watershed contour angle.

4. The method as claimed in claim **1** wherein forming the watershed image includes merging two of the watershed segments directly connected to one another and the watershed segments having the segment weight less than or equal to the segment threshold.

5. The method as claimed in claim **1** wherein forming the segmentation contour map includes forming the straight line segments by approximating the watershed segments as straight line segments parallel to a watershed contour angle.

6. A method of operation of an image processing system comprising:

receiving a source image having source pixels;

forming a homogeneity image having homogeneity pixels each with a homogeneity value, the homogeneity value is the magnitude of the sum of a set of target vectors extending from a target pixel to the source pixels of a local window;

forming a watershed image by segmenting the homogeneity image, the watershed image having watershed segments with a segment weight;

merging one of the watershed segments with another of the watershed segments with both of the watershed segments having the segment weight less than or equal to a segment threshold;

forming a segmentation contour map having the boundaries of the watershed segments formed by merging the watershed segments; and

forming a composite image with the segmentation contour map overlaying the source image for display on a device.

7. The method as claimed in claim **6** wherein forming the homogeneity image includes:

calculating the target vectors having a target vector direction and a target vector magnitude, the target vectors extending from the target pixel to each of the source pixels in the local window;

calculating a homogeneity vector having the homogeneity value set to the magnitude of the sum of the target vector magnitude of all of the target vectors; and

calculating a homogeneity direction as the sum of the target vector direction for all of the target vectors.

8. The method as claimed in claim **6** wherein forming the watershed image includes calculating the segment weight for one of the watershed segments based on the value of the homogeneity value along a watershed contour angle.

9. The method as claimed in claim **6** wherein forming the watershed image includes merging two of the watershed segments directly connected to one another and the watershed segments having the segment weight less than or equal to a segment threshold.

10. The method as claimed in claim **6** wherein forming the segmentation contour map includes forming the straight line segments by merging the watershed segments as straight line segments.

* * * * *